

Claims

1. A tissue ablation apparatus comprising:

a source of microwave radiation;

5 a probe for directing the microwave radiation into the tissue to be ablated;

a local oscillator for producing a signal having a different frequency to said microwave radiation;

10 a first detector for detecting the magnitude and phase of microwave radiation reflected back through the probe towards the source, said first detector being connected to said local oscillator, and

an impedance adjuster having an adjustable complex impedance, between said source and said probe.

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2. A tissue ablation apparatus for ablating tissue comprising:

a source of microwave radiation having a frequency;

20 a probe connected to said source, said probe being configured for directing said microwave radiation into said tissue to be ablated;

a local oscillator for producing a signal, having a frequency different to said frequency of said microwave radiation;

25 a first detector for detecting the magnitude and phase of a reflected portion of said microwave radiation reflected back through said probe towards said source;

30 said first detector being configured to determine the magnitude and phase of said reflected portion of said microwave radiation on the basis of said signal produced by said local oscillator and said reflected radiation; and

an impedance adjuster having an input connected to said source of microwave radiation and an output connected to said probe, said input and output having respective complex impedances, said complex impedance of said output being adjustable.

3. An apparatus according to claim 1 or claim 2 further comprising a second detector for detecting the magnitude and phase of forward directed microwave radiation directed from said source toward said probe, said second detector being connected to said local oscillator or a different local oscillator.

4. An apparatus according to claim 3 further comprising a third detector for detecting the magnitude and phase of either forward directed microwave radiation or reflected microwave radiation, said third detector being connected to said local oscillator or a different local oscillator.

5. An apparatus according to any one of the preceding claims wherein the or each detector comprises a mixer for mixing the signal from the local oscillator with the microwave radiation being detected by said detector.

6. An apparatus according to any one of claims 1 to 4 wherein the detector or detectors take the form of one or more power sensors and a phase comparator connected to said local oscillator.

7. An apparatus according to any one of the above claims wherein the or each local oscillator is separate from said source of microwave radiation.

8. An apparatus according to any one of the above claims wherein the or each local oscillator is connected to said source of microwave radiation and configured to produce a signal derived from said source, but having a different frequency to the frequency of said microwave radiation.

9. An apparatus according to any one of the above claims further comprising a controller for automatically adjusting said adjustable complex impedance of the impedance adjustor on the basis of the magnitude and phase of the radiation detected by said detector(s).

10. An apparatus according to claim 9 wherein said controller is configured to adjust said adjustable complex impedance dynamically in response to the variation in the magnitude and phase of the radiation detected by said detector(s).

11. An apparatus according to any one of the above claims where said probe is configured to penetrate biological tissue.

12. An apparatus according to any one of the above claims and having a separator for separating reflected microwave radiation from forward directed microwave radiation being directed towards the probe.

13. An apparatus according to any one of the above claims wherein the impedance adjuster is a stub tuner.

14. An apparatus according to any one of the above claims wherein there is a coupler for directing some of the reflected radiation to the first detector.

5 15. An apparatus according to any one of the above claims wherein the probe is coaxial.

16. An apparatus according to any one of the above claims wherein the probe is a waveguide.

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17. An apparatus according to any one of the above claims wherein the probe has an outer diameter of less than 1mm.

15 18. A microwave tissue ablation apparatus according to any one of claims 1 to 17 wherein the source of microwave radiation produces radiation of wavelength λ , and a radiation channelling means for conveying microwave radiation connects said impedance adjuster and said
20 probe, said channelling means having an adjustable length whereby the combined length of said channelling means and said probe can be adjusted to be equal to a multiple of $\lambda/2$.

25 19. A method of ablating tissue comprising the steps of:

using a source of microwave radiation to provide microwave radiation;

30 placing a probe in contact with or inserting a probe into biological tissue;

directing said microwave radiation through said probe into the tissue to ablate the tissue;

detecting the magnitude and phase of microwave radiation reflected back through the probe by using a first detector and a local oscillator, and

5 adjusting the complex impedance of an impedance adjustor between said source and said probe on the basis of the magnitude and phase of the microwave radiation detected by said first detector.

10 20. A method of ablating tissue comprising the steps of:

using a source of microwave radiation to provide microwave radiation having a frequency;

placing a probe in contact with or inserting a probe into biological tissue;

15 directing said microwave radiation from said source through an impedance adjuster and then through said probe into said tissue to ablate the tissue; said impedance adjustor having an input connected to said source and an output connected to said probe, said input and said
20 output having respective complex impedances;

detecting the magnitude and phase of reflected microwave radiation reflected back through the probe by using a first detector and a local oscillator; said local oscillator generating a signal having a frequency
25 different to said frequency of said microwave radiation, said first detector using said local oscillator signal in combination with the reflected radiation or a signal derived from said reflected radiation to determine the magnitude and phase of said reflected radiation;

30 and adjusting said complex impedance of said output of said impedance adjustor on the basis of said magnitude and phase of said reflected microwave radiation detected

by said first detector, so as to minimise the amount of microwave radiation which is reflected back through said probe.

5 21. A method according to claim 19 or 20 wherein the probe is inserted into the tissue so that an end of the probe is proximate to or inside a cancerous tumour in the tissue and microwave radiation is then passed through the probe to ablate said cancerous tumour.

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22. A method according to claim 21 wherein the microwave radiation is used to cut a path in the tissue so that the probe can be inserted near to or into said tumour.

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23. A method according to claim 20 wherein the magnitude and phase of forward directed microwave radiation directed toward said probe from said source of microwave radiation is detected by using a second detector and said local oscillator or a different local oscillator and said adjustable complex impedance of said impedance adjuster is adjusted based on the magnitude and phases detected by said first and second detectors.

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25 24. A method according to claim 23 wherein a third detector is used to detect the magnitude and phase of either forward directed or reflected radiation and said adjustable complex impedance of said impedance adjuster is adjusted on the basis of information provided by said first, second and third detectors.

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25. A method according to any one of claims 19, 20, 23 or 24 wherein said adjustable complex impedance of said impedance adjuster is adjusted automatically by a control means on the basis of said magnitude and phase detected by said detector(s) so as to minimise the amount of microwave radiation reflected back through the probe.

26. A method according to claim 25 wherein the impedance adjustment is carried out dynamically as the detected magnitude and phase varies.

27. An elongate microwave probe for delivering microwave radiation into tissue to be ablated, said probe having an elongate portion and a tip at one end of said elongate portion, said tip being formed of a ceramic material and being configured to deliver microwave radiation into tissue.

28. A coaxial tissue ablation probe having an inner conductor, a dielectric surrounding said inner conductor, a conducting sheath surrounding said dielectric and one or more baluns on said sheath, the or each balun comprising a spray-on dielectric.

29. A probe according to claim 28 wherein the or each balun further comprises an outer conductor surrounding said spray-on dielectric.

30. A probe according to claim 28 or 29 wherein said probe is designed for use with microwave radiation of wavelength λ and the or each said balun has a length in

the direction of the axis of said probe of $\lambda/4$ or odd multiples thereof.

5 31. A method of making a balun for a coaxial tissue ablation probe comprising the steps of spraying or otherwise placing a liquid or powder dielectric onto an outer surface of an outer conducting sheath of a coaxial probe, and if said dielectric is liquid allowing the liquid to solidify, to form the balun.

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32. A method according to claim 31 comprising the further step of and placing an outer conductor around said dielectric.

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33. A method according to claim 32 wherein said probe is designed for use with a microwave radiation of wavelength λ and the balun has a length in the direction of the axis of said probe of $\lambda/4$ or odd multiples thereof.

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34. A surgical apparatus comprising:

a source of microwave radiation of a first frequency suitable for ablating tissue;

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a probe for directing microwave radiation from the source into tissue to be ablated;

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a modulator having an OFF state in which it does not modulate said microwave radiation from the source so that the unmodulated microwave radiation is directed through the probe and an ON state in which it modulates microwave radiation from the source in pulses having a second frequency less than said first frequency; said

second frequency being suitable for cutting tissue and in the range of 10KHz to 500MHz

5 35. An apparatus according to claim 34 wherein the apparatus further comprises a low pass filter between said modulator and said probe; said low pass filter having a first state in which it lets said first frequency pass and a second state in which it passes said second frequency, but filters out said first frequency.

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36. An apparatus according to claim 35 wherein said modulator is capable of varying said second frequency.

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37. An apparatus according to claim 35 wherein said modulator is capable of varying said second frequency and said low pass filter is capable of varying its pass band in its second state.

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38. An apparatus according to any one of claims 34 to 37 wherein said first frequency is 5GHz or higher.

39. An apparatus according to any one of claim 34 to 38 wherein said second frequency is a frequency in the range 500kHz to 30MHz.

AMENDED SHEET